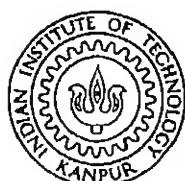


A COMPARATIVE STUDY OF LATERITE AND BLACK COTTON SOIL PROFILES

By

ABATE TADESSE W KIRKOS

CE
1986
M
KIR
Com



DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
APRIL 1986

A COMPARATIVE STUDY OF LATERITE AND BLACK COTTON SOIL PROFILES

A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of

MASTER OF TECHNOLOGY

By

ABATE TADESSE W. KIRKOS

to the

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
APRIL 1986

157 86

92031

To

TADESSE AND MEKBIB

LIST OF TABLES

TABLE		Page	
2.1	: Weathering Stages and Representative Minerals in Soils	...	5
4.1	: Coarse and Clay Fractions of Samples from Profiles I & II	...	29
4.2	: Natural Moisture Content of Samples from Profiles I & II	...	30
4.3	: Organic Matter Content of Samples from Profiles I & II	...	32
4.4	: Cation Exchange Capacity of Samples from Profiles I & II	...	33
4.5	: Coarse and Clay Fractions of Samples from Profile III	...	35
4.6	: Organic Matter Content of Samples from Profile III	...	36
4.7	: Cation Exchange Capacity of Samples from Profile III	...	37
5.1	: Summary of Index Properties of Samples from Laterite and Black Cotton Soil Profiles	...	40

LIST OF FIGURES

Figure		Page	
2.1	: Solubility-pH Diagram Showing conditions for Laterite Formation	...	7
2.2	: Schematic Representations of the Structural Units of Kaolinite, Montmorillonite and Gibbsite Clay Minerals	...	9
2.3	: Clay Type As a Function of Rainfall	...	10
2.4a	: Stability Diagram for Gibbsite, Kaolinite and Na-Montmorillonite at 25°C	...	11
2.4b	: Stability Diagram for Gibbsite, Kaolinite, Anorthite and Ca-Montmorillonite at 25°C	...	12
2.4c	: Stability Diagram for Gibbsite, Kaolinite, Muscovite and K-Feldspar at 25°C	...	14
4.1	: Two Laterite Soil Profiles (Profiles I & II) and Pune Black Cotton Soil Profile (Profile III) (Not to Scale)	...	23
4.2	: Sketch of X-Ray Diffraction Patterns of Laterite Profile L-I	...	27
4.3	: Thin Section View of Calicut Quarry Bed Rock Sample, 100 X	...	28
4.4	: Sketch of X-Ray Diffraction Patterns of Pune Black Soil Profile (Profile III).		34

LIST OF PLATES

PLATE		Page
3.1	: Calicut Freshly Dug Pit (Profile I)	... 16
3.2	: Calicut Quarry (Profile II)	... 17

ABSTRACT

Weathering of bed rock to soil involves physical and chemical changes. The results of these changes were studied in two laterite soil profiles near Calicut, Kerala and in a Black Cotton soil profile near Pune, Maharashtra. The physical changes at the interface between bed rock and partly weathered c-horizon can be quantified in terms of saturation moisture content. ⁹ *what do you
see by
submerging
soil in
moisture
content* Typical values are 2% in Calicut bed rock, 6% in laterite profile and 18% in Black soil profile. The chemical changes are reflected primarily ^{due} in the variation in mineralogy. Other variables are grain size distribution, moisture content, organic matter content, pH and cation exchange capacity (CEC).

CEC of both soils is controlled by organic matter, clay type and percentage of clay fraction. The highest CEC of 89 meq/100 g was observed in the near surface a-horizon of montmorillonite rich black soil. The laterite soil containing kaolinite and gibbsite has CEC around 32 meq/100 g near surface. Both soils show a decrease in CEC as organic matter decreases with depth or when ⁿ organic matter is removed by H_2O_2 treatment.

The general sequence of tropical weathering is deciphered to be (1) break down of feldspar and pyroxene, (2) formation of montmorillonite rich black soil under poor drainage condition, (3) formation of kaolinite under intense leaching, & (4) final accumulation of gibbsite, goethite and amorphous iron oxide with cementation of clay particles at the top of a laterite soil profile.

CHAPTER 1

INTRODUCTION AND OBJECTIVES

The importance of soil studies hardly needs elaboration. In addition to well known applications in agriculture, ground water exploration, slope stability and civil engineering construction, there is a growing need of soils for waste disposal sites. Most civil engineering projects have to deal with soil properties. The engineering behaviour of soils is expressed in terms of the variation of certain index properties in response to natural and man-made stress levels. On the other hand, it has been realized that their index properties are strongly dependent on the environment of soil formation.

Soil is known to be the product of interaction of the parent material with climate, organisms, topography and time. All these factors affect the rate of weathering of the fresh rock. The net effects of weathering are : (1) the physical reduction in particle size and (2) the chemical decomposition of primary minerals and formation of new minerals. These two processes give rise to various layers or horizons in the soil profile starting from top soil, rich in organic matter, to a horizon containing partly weathered bed rock.

Chemical weathering reactions in particular are most extensive in tropical climates because of relatively high

temperature and abundant rainfall. Therefore, soil profiles are most clearly developed in tropical climates. The two major residual soil types of India are Lateritic soils and Black Cotton Soil. Laterite was first discovered in the state of Kerala where great thickness of red soil profiles are found over Precambrian basement rocks like Charnockite and Peninsular Gneiss. The type area of Black Cotton soil is the Deccan Basalt Outcrop in Central and Western India.

In this thesis two typical profiles are studied in detail to assess the effect of soil formation processes on index properties. One is a laterite profile near Calicut, Kerala. The other is a black soil profile near Pune, Maharashtra. The main objectives of this work were

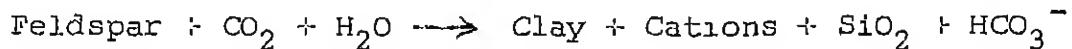
- (1) To map the soil profile in field, recording the thickness of individual horizons and physical properties like colour, granularity, etc.
- (2) To collect representative samples for laboratory determination of index properties.
- (3) To scan the profiles for mineralogy by X-ray diffraction technique.
- (4) To correlate mineralogy, grain size variation and organic matter content with cation exchange capacity.
- (5) To establish the difference in degree of weathering and index properties between laterite and black cotton soil.

CHAPTER 2

PREVIOUS WORK

2.1 WEATHERING PROCESS:

Rocks and minerals at the earth surface adjust to the greatly reduced temperature and pressure conditions in the soil environment. The process of adjustment is broadly called weathering. The agents and energies that activate weathering processes have been classified into physical and chemical types. In physical weathering, rock materials are broken into smaller fragments by mechanical forces, whereas, in chemical weathering there is a change in the chemical composition of the original rock due to removal of ions and formation of new minerals (Corroll, 1970). The most important agent of chemical weathering is dissolved CO_2 derived from atmospheric and biogenic sources. The mildly acidic H_2CO_3 solution attacks rock forming minerals through an exchange of cations by H^+ ions. For example,



Other important weathering reactions include complete dissolution of carbonate minerals and oxidation of iron. The net effect of weathering ^{are} ~~is~~: (1) the physical reduction in particle size and (2) formation of hydrated silicate and oxide minerals (Foth, 1984).

2.2 WEATHERING AND SOIL FORMATION:

One of the most significant results of the weathering of the bed rock is the development of residual soil profiles. A vertical section through the soil shows various horizons starting with the zone of leaching at the surface followed by zone of accumulation, a zone of partly weathered rock and finally the fresh bed rock. In the nomenclature of soil scientists these are commonly termed as the A, B, C and D horizons (Foth, 1984). *Should be small letters*

The chemical reactions which lead to soil formation have relatively fast rates under tropical climates. At the same time abundant rainfall leaches away the soluble products of weathering reactions. In many tropical countries including India the two important residual soil types are the red soil (lateritic) and the black soils (black cotton soils). At many locations a single parent material gives rise to red soil under adequate drainage and black soil when drainage is poor (Lunkad and Raymahashay 1978; Rao and Krishna Murti, 1985).

The difference in the weathering resistance of minerals are were used by Jackson and Sherman to establish 13 weathering stages that relate mineralogical composition of soils to weathering intensity. Representative minerals with the weathering stages are given in Table 2.1 (Foth, 1984).

Table 2.1

WEATHERING STAGES	REPRESENTATIVE MINERALS
EARLY WEATHERING STAGES	
1	Gypsum (also halite, sodium nitrate)
2	Calcite (also dolomite, apatite)
3	Olivine-hornblende (also pyroxene)
4	Biotite (also glauconite, nontronite)
5	albite (also anorthite, microcline, orthoclase)
INTERMEDIATE WEATHERING STAGES	
6	Quartz
7	Muscovite (also hydrous mica)
8	2:1 layer silicates (including vermiculite, expanded hydrous mica)
9	Montmorillonite
ADVANCED WEATHERING STAGES	
10	Kaolinite
11	Gibbsite
12	Hematite (also goethite, limonite)
13	Anatase (also rutile, zircon)

2.3 CHEMISTRY OF WEATHERING :

Two major processes during rock weathering are (1) leaching of exchangeable ions and (2) removal of silica with

consequent accumulation of Al_2O_3 and Fe_2O_3 . The solubility of SiO_2 , Fe_2O_3 and Al_2O_3 is a function of pH as shown in Fig.2.1.

As is obvious, under natural water pH values of 6 to 8, silica is more soluble than Al_2O_3 and Fe_2O_3 . This leads to the formation of bauxite and laterite at the most advanced stage of tropical weathering.

Many workers have suggested that one chemical criterion to classify lateritic soil is that the ratio of SiO_2 to Fe_2O_3 : Al_2O_3 should be between 1.33 and 2.0. (See for example Ola, 1978). More recently a mineralogical extension of the same criterion has been suggested where the relative proportion of kaolinite, gibbsite and goethite has been used to distinguish laterites from bauxites (Aleva, 1981).

Gidigasu (1976) distinguished three major stages of laterisation : (1) Decomposition of primary minerals (2) combined leaching of silica and bases with enrichment of sesquioxides and (3) partial or complete dehydration sometimes involving hardening.

It has been observed that removal of free iron oxide coatings from lateritic soils improves X-Ray peaks of clay minerals, increases clay size fraction, modifies cation exchange capacity values (Rao and Raymahashay, 1981).

The main difference between lateritic and black soils is the occurrence of montmorillonite in the latter. Various factors

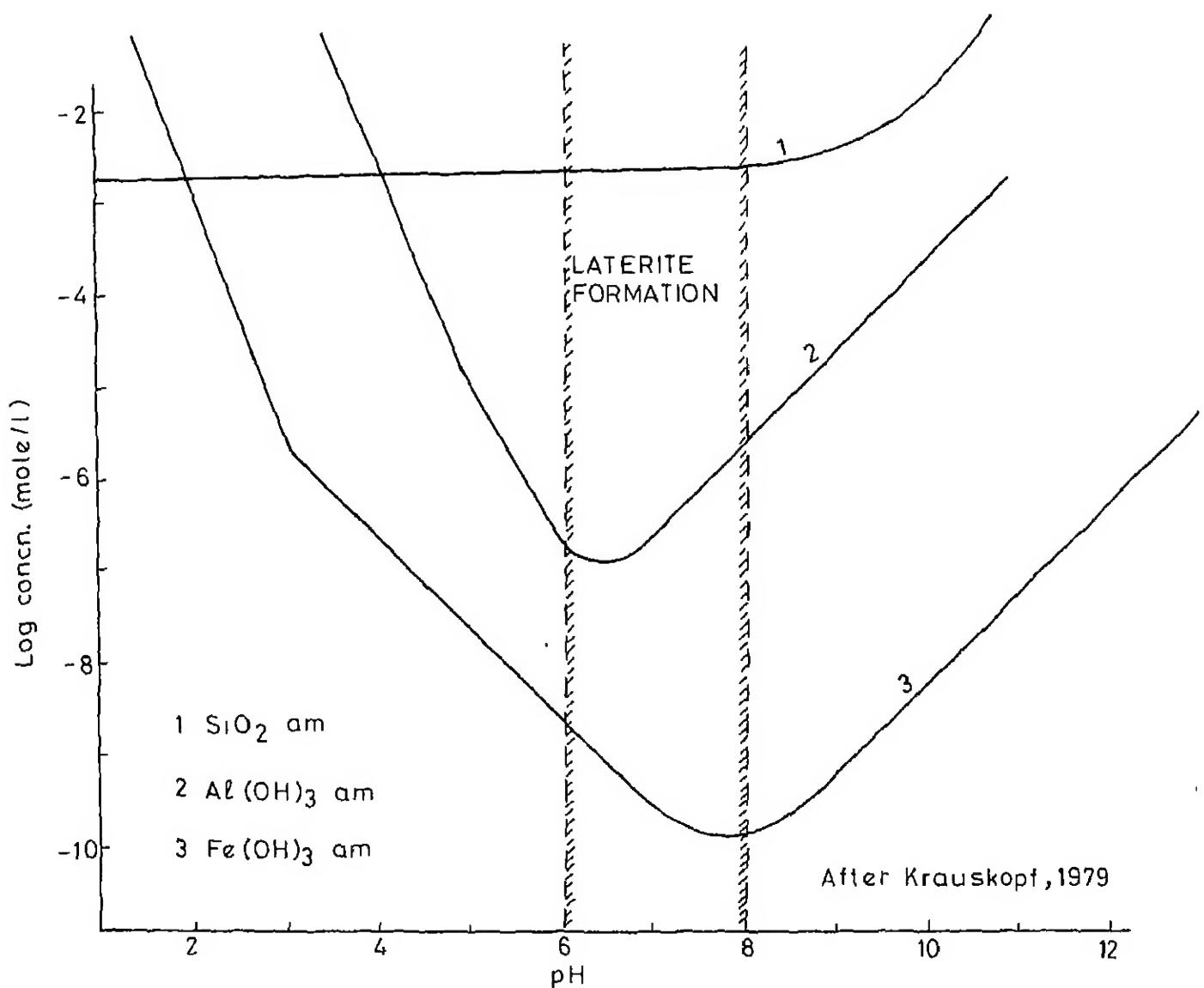


Fig. 2.1

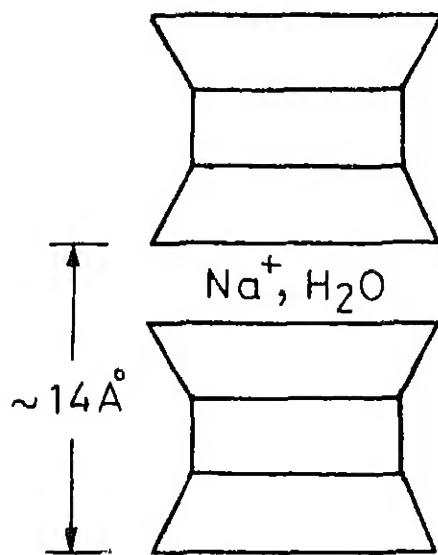
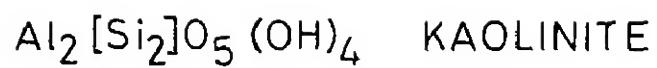
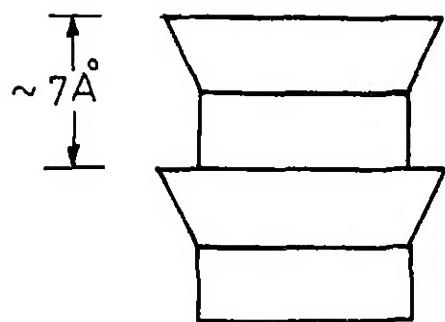
have been found to control the development of kaolinite and montmorillonite in soil profiles.

2.4 KAOLINITE VERSUS MONTMORILLONITE :

Weathering can be considered to be a process of progressive leaching of cations and silica from the primary silicate minerals in the bed rock. The extent of leaching is accelerated at relatively high temperature and high rainfall. Therefore, tropical climates are most favourable for advanced stages of weathering and soil formation. Starting from tightly bonded feldspar structure, there is successive transformation to 3-layer structure of montmorillonite, 2-layer structure of kaolinite and finally the single layer Al(OH)_3 or Fe(OH)_3 structure (Fig. 2.2).

The development of kaolinite vs. montmorillonite in tropical soils has been found to be directly related to rainfall (Fig. 2.3).

For the primary minerals to lose cations and silica, the local ground water is the most obvious leaching agent. The thermodynamic stability of the secondary minerals thus depends on the concentration of released ions in ground water. This situation can be depicted through Garrels type ion activity diagrams. (In Fig. 2.4 are) stability diagrams developed by Tardy (1971). Ground water compositions from black soil over Deccan Basalt (Lunkad and Raymahashay, 1978) are plotted on the Na and Ca- system diagrams (Fig. 2.4a & b) and composition of



Na - MONTMORILLONITE

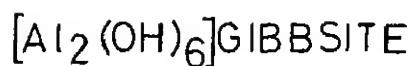
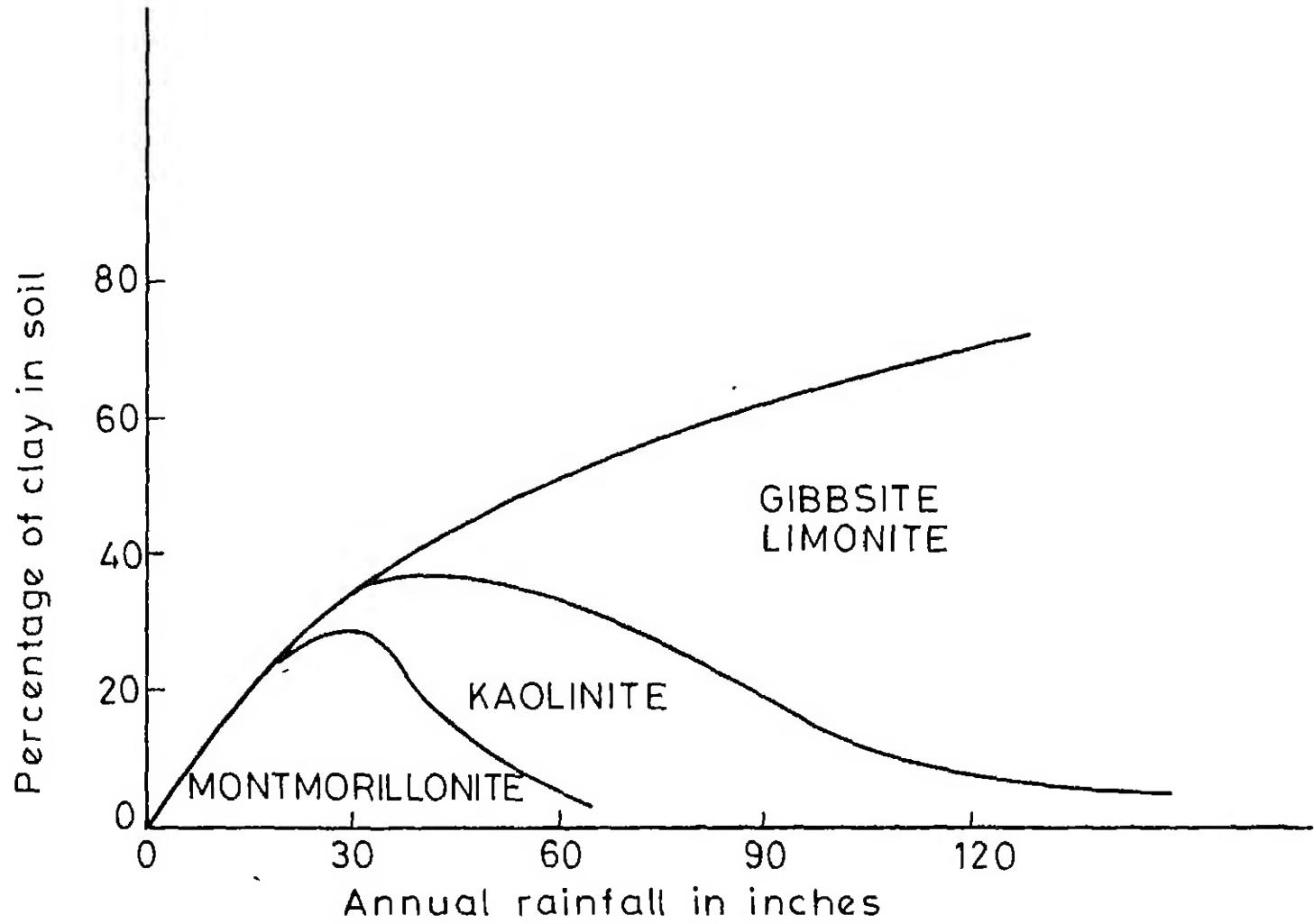


Fig. 2.2



AFTER GIDIGASU (1976)

Fig. 23

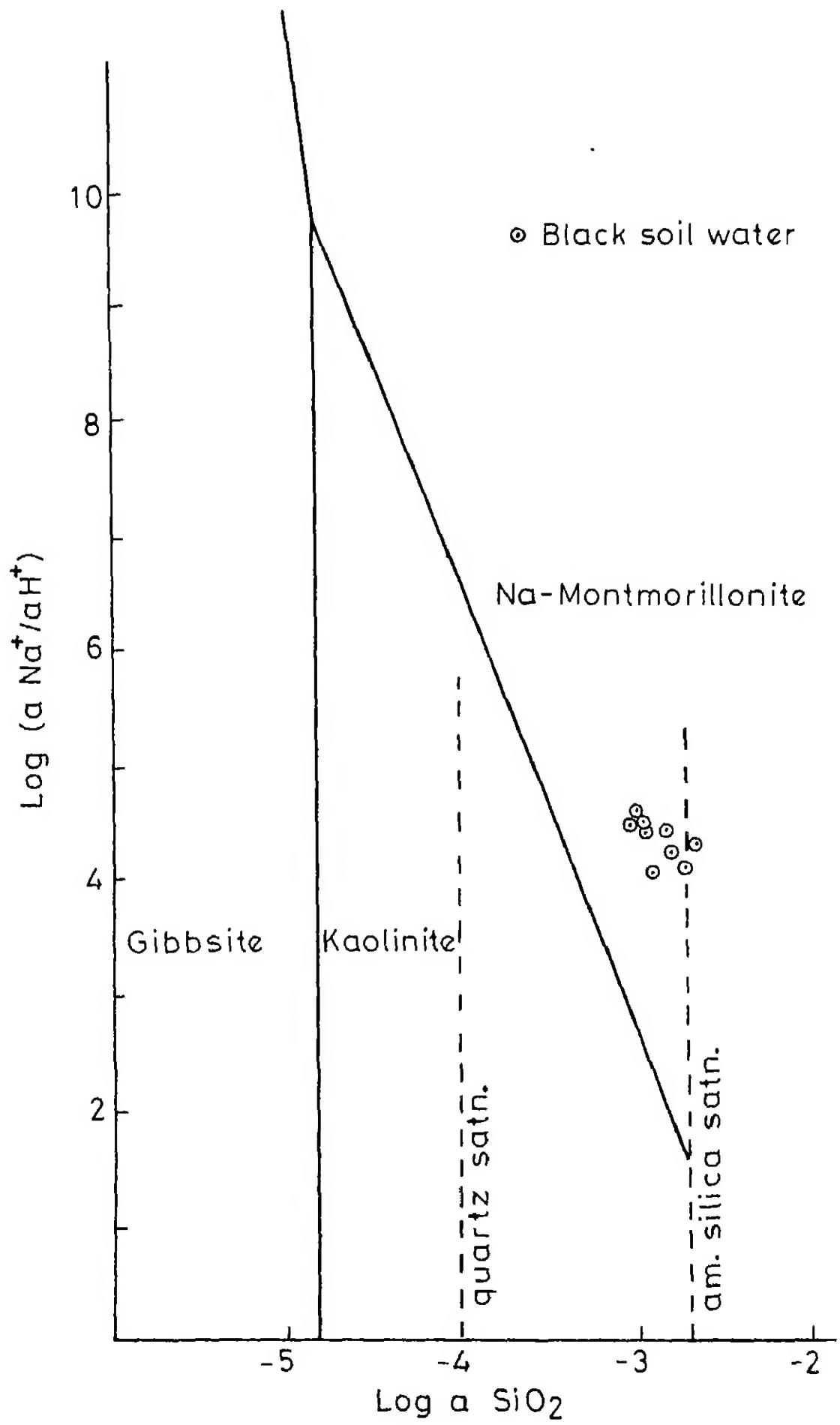


Fig. 2.4a

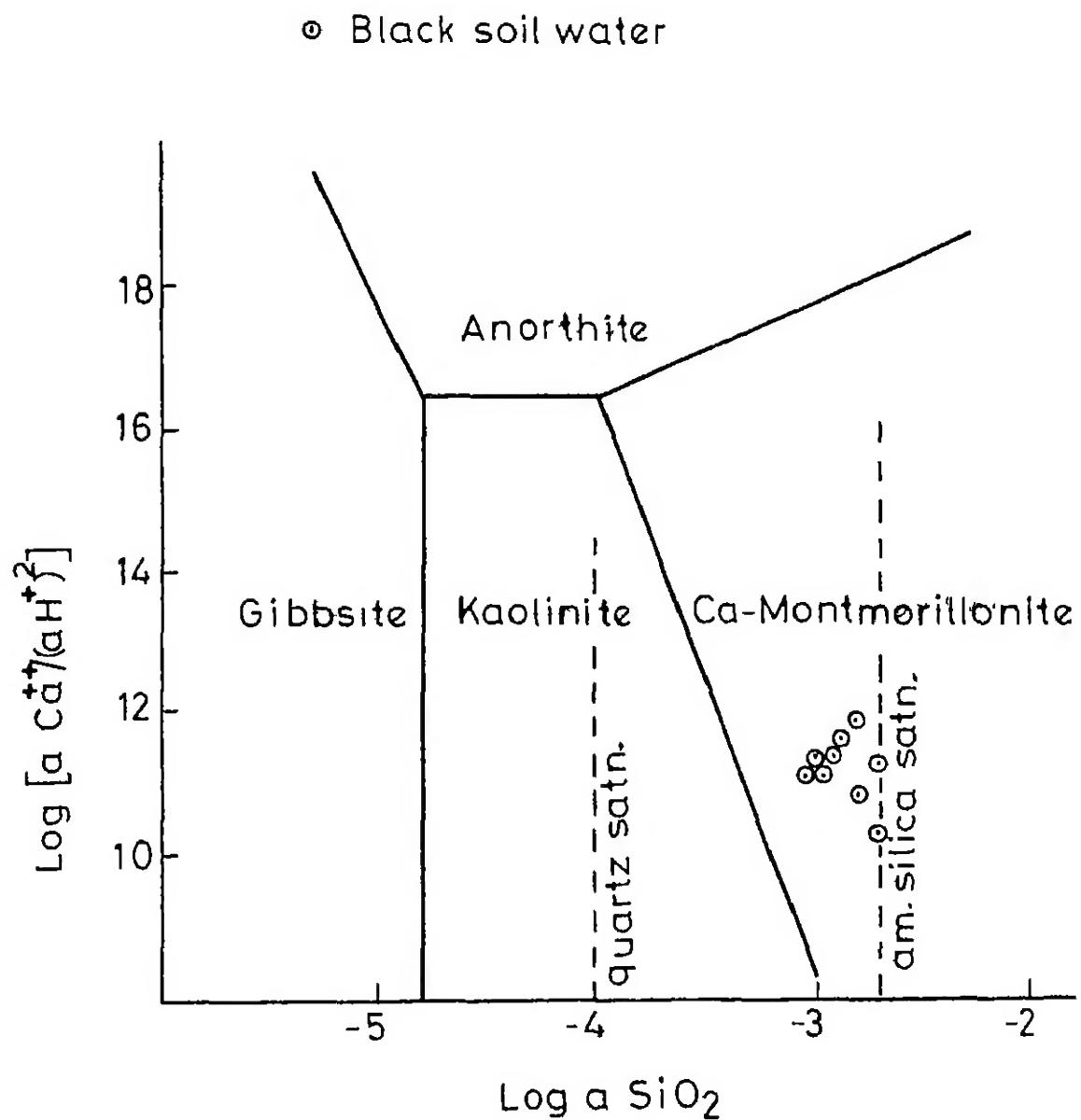


Fig. 2.4b

typical well water from Calicut Laterite (Raymahashay et al, 1985) has been plotted on the K-system diagram (Fig. 2.4c). It is clear that laterite water has lower a K^+ / aH^+ ratio and a SiO_2 and plots in the Kaolinite stability field. At higher SiO_2 activity and relatively high a Na^+ / aH^+ and a $Ca^{++} / (aH^+)^2$ ratios montmorillonite is stable in the water from Black soils.

2.5 ION EXCHANGE PROPERTY

Clay minerals have the capacity for cation exchange because exchangeable ions are held around and in between the silica alumina structural units. In the case of kaolinite, the cation exchange capacity (CEC) is mostly due to broken bonds at the edges. The number of broken bonds and hence CEC increases as the particle size decreases. Lattice distortion and isomorphous substitution can also have limited contribution towards CEC. The usual range of CEC of Kaolinite is from 3 to 15 meq/100gm.

For montmorillonite 80% of cation exchange capacity is due to isomorphous substitution and the rest is due to broken bonds. The unbalanced charges are satisfied by exchangeable cations present mostly in the inter layer position and some at the particle edges. The range of CEC for montmorillonite is 80 to 150 meq/100 gm. (Grim, 1953).

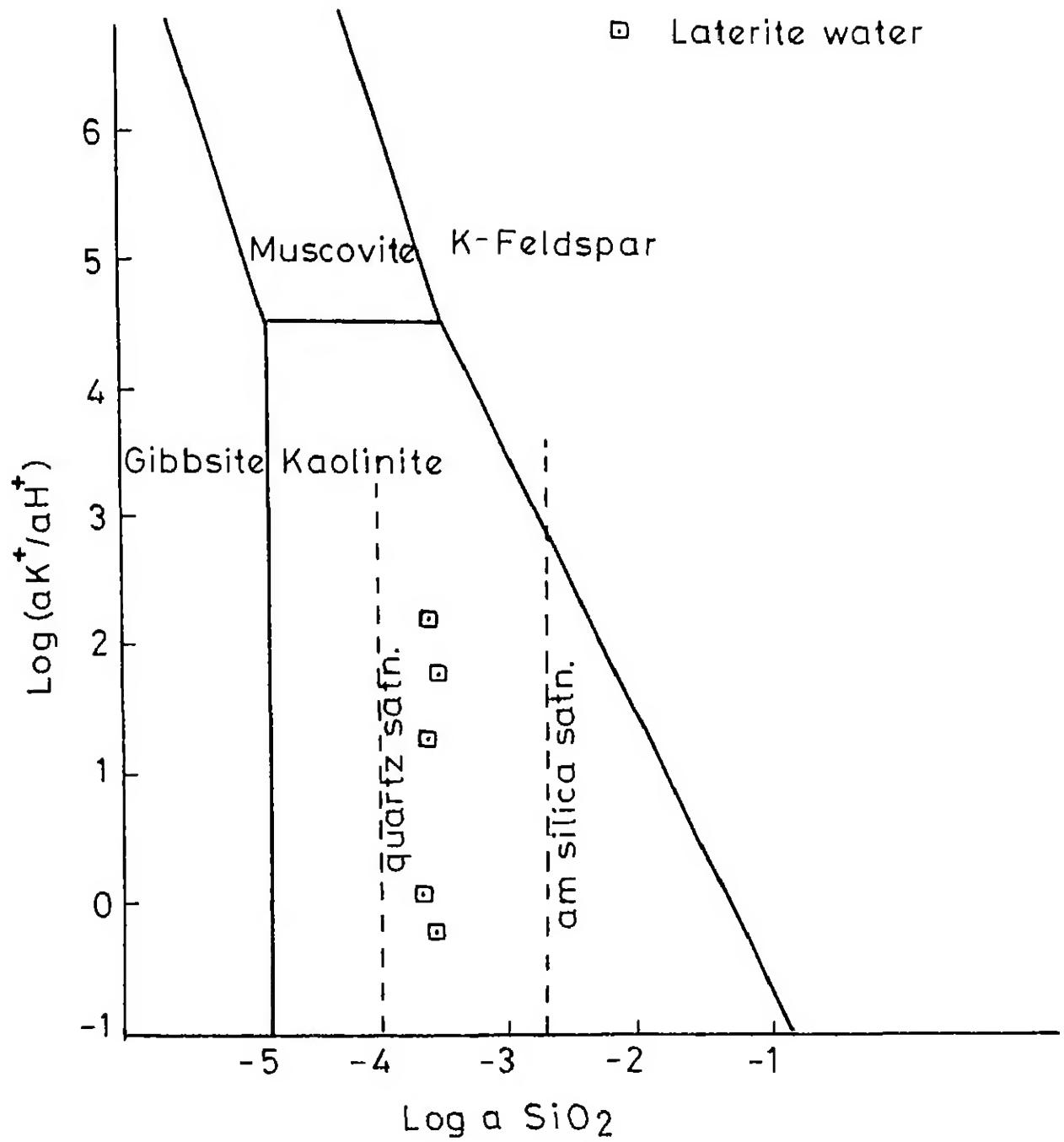


Fig. 2.4c

CHAPTER 3

METHOD OF WORK

3.1 FIELD WORK:

The two laterite profiles are situated near the Regional Engineering College, Calicut, Kerala. The REC is situated at Chattamangalam about 23 km. east of Calicut town. Profile L-II is in a freshly dug pit near the Government secondary school at REC. The pit was dug using an ordinary pick and an auger. The thickness of various visibly distinct layers was measured with a tape (Plate 3.1). It was observed that the soil is wetter and softer towards the bottom of the pit about 4.6 m deep. A clay zone, greyish in colour could be distinguished below the reddish laterite on top.

Profile L-II was observed in a stone quarry situated at Kattangal, about one km. away from REC. A dark coloured rock with white quartz lenses is being excavated by explosives. A thin soil profile was measured on top of this bed rock. The total depth is about 2.4 m (Plate 3.2).

The Black soil (Profile III) occurs at Markal, 40 km. east of Pune, Maharashtra. The samples were obtained from Mr. Ajit V. Kulkarni of the Geology Department, University of Pune.

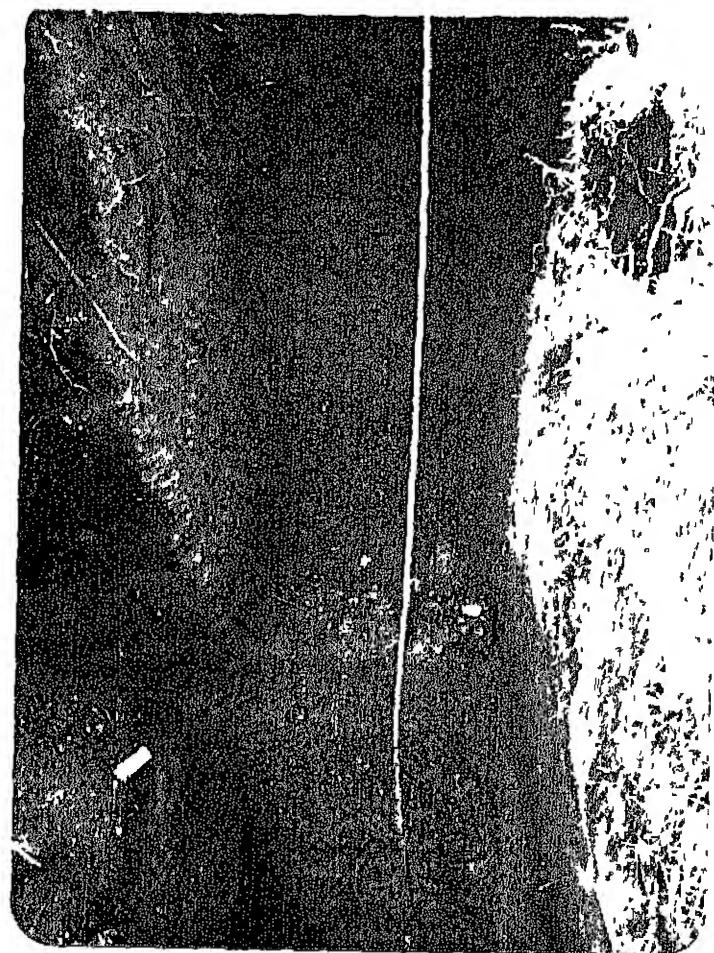


PLATE 3.1



PLATE 3.2

3.2 LABORATORY WORK:

The soil sample was air dried and the part of soil which passes through Sieve No. 80 (ASTM) was retrieved and used for further work.

3.2.1 pH :

About 10 gms of air dried soil was taken in a beaker and 40 ml of distilled water was added to make 1:4 suspension. After stirring it, it was left to settle and the pH of the top layer of the solution was determined by using a Systronics Grip pH - meter.

3.2.2 MOISTURE CONTENT :

To determine the natural moisture content of the soil about 20 gm of the original soil sample was accurately weighed and put into an 110°C oven. After 24 hours, it was taken out and the weight loss was determined.

3.2.3 REMOVAL OF ORGANIC MATTER :

About 10 gms of soil was taken in a beaker and 10-20 ml of distilled water was added to make up the suspension to 1:1 to 1:2 soil-to-water ratio. The soil suspension was heated to about 60-80°C and 30% hydrogen peroxide (H_2O_2) was added drop by drop while stirring. Addition of H_2O_2 was continued until the sample ceased to froth. After that the suspension

was filtered using Whatman 42 filter paper and washed with distilled water. The residue was allowed to dry at room temperature and the organic matter content was determined by weight loss. It is understood that this treatment with H_2O_2 does not completely oxidize the organic matter. However, it is a quick method to determine the order of magnitude of soil organics (Jackson, 1958).

3.2.4 CLAY CONTENT :

About 300 gm of oven dried soil is taken and the finer material passing through sieve No. 200 was collected. This soil passing the No. 200 sieve is saved for further analysis. The soil retained on the No. 200 sieve is thoroughly washed with water till clear water passes through the sieve. Afterwards, it is oven dried until constant weight is obtained. Then, the percentage of the soil retained on No. 200 sieve is determined. A hydrometer analysis is made by taking 40 gm of the soil passing the No. 200 sieve. This test involves first soaking the 40 gm of soil over night in a sodium hexametaphosphate solution in order to facilitate dispersion. Then, it is placed in a metal cup with baffles on the inside, and it is dispersed for 10 minutes by the soil mixer running at a speed of 16,000 revolutions per minute. The soil mixture is poured into the cylinder and distilled water is added to bring the contents up to one litre. By closing the mouth of the cylinder, it is inverted 3 to 5

times to make the soil suspension thoroughly suspended and then it is kept on a level and stable table and the time immediately noted. The rate of fall of suspended particles is related to size(sand settling faster than silt, and silt settling faster than clay) according to stokes law. Hence, the percentage of clay in the soil passing No. 200 sieve is determined from the gradation curve drawn. Then, the percentage of clay in the total soil is calculated as the percentage of soil retained on No.200 sieve, is known.

3.2.5 CATION EXCHANGE CAPACITY :

From the sieved fraction about 1 gm of accurately weighed soil is taken. This is put on a filter paper (Whatman No. 40) which is kept in a Buchner funnel. Then, the soil is saturated with 50 ml of 0.2 N potassium acetate. Then, the soil is washed with about 70 ml of distilled water. Then, a fresh graduated cylinder is kept below the funnel and the soil is washed with 50 ml of 1 N ammonium acetate. The volume of solution collected in the graduated cylinder is noted and the exchangeable potassium in solution is analysed by Flame photometry and the exchangeable K^+ expressed in meq/100 gm of soil (Modified after Indian Standard, 1967).

The same is repeated for the soil treated with 30% H_2O_2 to determine the CEC of the soil without organic matter.

3.2.6 QUICK WATER ABSORPTION TEST :

This is done for the weathered rock and fresh rock of the Calicut quarry as well as for the weathered basalt on which the black soil of Pune has developed.

About 100 to 250 gm of rock is taken and kept in an 110°C oven for 24 hours. (Then) the dry weight (W_1) is accurately noted. (Then, the sample is soaked in water for about one hour and is then taken out of the water. The excess dripping water is dried by tissue paper and (this) sample saturated by quick absorption is accurately weighed (W_2). (Then) the quick absorption is determined by applying the following formula

$$\text{Absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

3.2.7 X-RAY DIFFRACTION :

About 2 gm of soil was mixed with 50-100 ml of distilled water in a cylinder and heavier fraction (quartz, etc) was allowed to settle for about 10 minutes. Middle fraction of the soil suspension was taken out by a pipette and spread over a glass slide. The slide was allowed to dry at room temperature. This technique lets the flaky particles to orient themselves parallel to their basal planes and the identification of basal peak is easier in X-ray diffraction.

All the oriented slides as well as bulk powder samples were scanned by X-ray diffraction in an ISO-DEBYEFLEX-2002 (SEIFERT), 30 KV X-ray diffractometer using CuK_α radiation.

CHAPTER 4

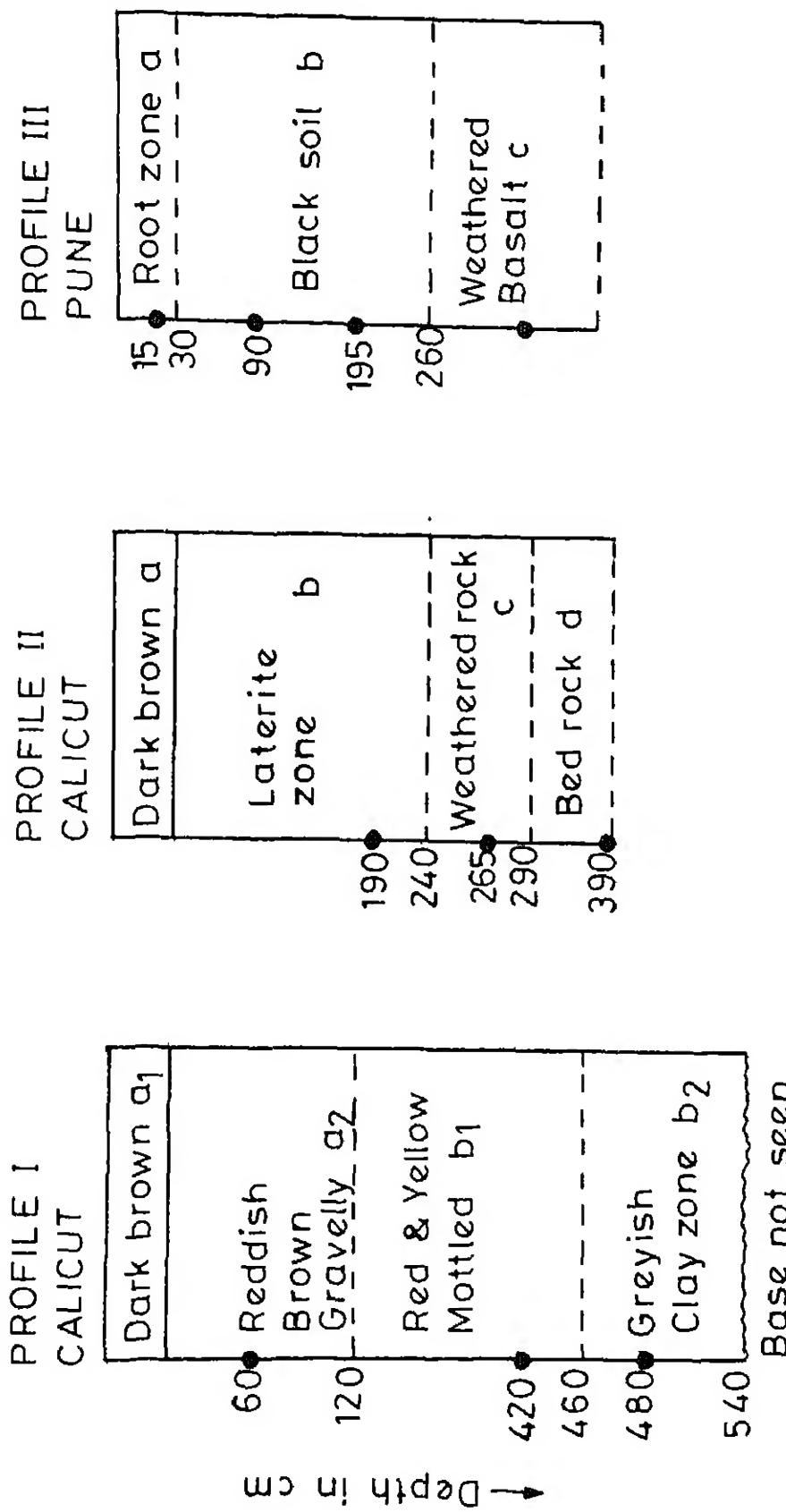
RESULTS AND INTERPRETATION

4.1 DESCRIPTION OF SOIL PROFILES:

Two separate laterite profiles from Calicut area and one black soil profile from Pune area were chosen for study. Profile L-I and Profile L-II are located near REC, Calicut whereas Profile III is located at Markal, about 40 km east of Pune. The locations of representative soil samples collected from each profile are indicated in Fig. 4.1

4.1.1 PROFILE L-I:

The horizons of the soil in this profile are well developed. The soil extends to 5.4 m and the base is not seen. The top soil marked 'a', is about 20 cm thick and is dark brown in colour. It is the horizon where dead leaves and grass roots are maximum. Below this zone is 'a₂' where the colour is not as dark as 'a₁' but is reddish brown and the soil is very gravelly and loose. The horizon 'a₂' extends to a depth of 1.2 m. The gravelly part diminishes in abundance and there is a gradual change towards red colour as we go further below 1.2 m. The soil becomes hard and blocks could be cut easily. This horizon is the zone of accumulation, rich in iron oxides indicated by its red and mottled (yellow) colour. This horizon termed 'b₁' extends gradually to the softer and wetter 'b₂' horizon (clay zone).



● SAMPLE LOCATION

Fig. 4.1

The transition is gradual but at about 4.6 m, the whole horizon below becomes sticky and whitish in colour (Plate 3.1). Samples were collected at 60 cm, 4.2 m and 4.8 m depth (referred hereafter as Cal 60, Cal 420 and Cal 480 respectively).

4.1.2 PROFILE L-II :

This profile is located at a quarry not very far from Profile L-I described above. The major difference is that a complete profile from bed rock to top soil is visible here (Plate 3.2). The profile upto a depth of 2.9 m is almost a vertical cut. The top 20 cm or so is dark brown in colour and is full of fallen leaves and grass roots. This has been termed as 'a' horizon. This is followed at depth by red laterite zone indicated as the 'b' horizon in Fig. 4.1. Unlike Profile L-I there is no mottling of lower part of the laterite zone and there is a sharp transition to zone of partly weathered rock called the 'c' horizon. This is a layered, fragmented yellowish rock which has retained some of the dark colour of the bed rock. Below this partly weathered zone is a huge mass of the dark coloured bed rock. This rock is quarried using explosives and then manually cut into blocks or broken to aggregate size chips. This zone of bed rock has been labelled as 'd' horizon in Fig. 4.1 and is located at a depth of about 2.9 m below the surface. Samples were collected from the 'b' horizon at 1.9 m (Cal 190) the 'c' horizon at 2.65 m (Cal 265) and also from the 'd' horizon below 2.9 m.

4.1.3 PROFILE III:

This is a black soil profile near Pune. The top 30 cm of the soil is full of grass roots and is labelled as the 'a' horizon in Fig. 4.1. Below this is the black soil zone ('b' horizon) which extends upto a depth of 2.6 m. At this depth a zone of partly weathered basalt occurs. The rock is highly friable and soft and disintegrates in water. However, it retains the jointed nature of the original basalt. Representative samples were collected from 'a' horizon (P-1), top of 'b' horizon (P-2), bottom of 'b' horizon (P-3) and also from the 'c' horizon as shown in Fig. 4.1. The base is not seen.

4.2 INDEX PROPERTIES OF LATERITE PROFILES :

Literature survey indicated that tropical soil profiles show extensive variation in a few index properties which can be determined easily by the field engineer. Since the samples collected for this study provided an opportunity to monitor variation with depth, the parameters selected were mineralogy, grain size variation, moisture content, organic matter content, pH and cation exchange capacity.

4.2.1 MINERALOGY :

Profile L-I was studied through three samples collected from 'a₂', 'b₁' and 'b₂' horizons (Fig. 4.1). A comparison of the X-ray diffractogrammes of the three samples showed the

following features. The Cal 60 sample at 60 cm depth contains quartz with broad and poorly defined peaks of kaolinite, gibbsite and possibly halloysite and goethite (Fig. 4.2). The clay peaks are remarkably sharpened in samples Cal 420 and Cal 480 (Fig. 4.2). The overall mineralogy remains to be quartz, kaolinite and gibbsite upto 4.8 m depth. It is apparent that the iron oxide coatings suppress the clay peak towards the top of the laterite zone. As there are only imperfect X-ray peaks of iron oxide minerals in these diffractograms, it is concluded that iron is present as X-ray amorphous hydroxide phases (limonite).

The sample from 1.9 m depth of profile L-II once again shows an assemblage of kaolinite-gibbsite-quartz. However, in this profile it was possible to study the mineralogy of the partly weathered zone and the bed rock. XRD of a powder sample at 2.65 m depth (c-horizon) showed prominent peaks of sodic plagioclase at 3.17, 3.20, 3.67, 3.79 and 6.3 \AA° . The other minerals are pyroxene (2.99 \AA), quartz (3.34 \AA) and mica (10 \AA). A sedimented slide of this sample shows a peak at 8.4 \AA which may be due to halloysite. A thin section prepared from the bed rock showed twinned laths of plagioclase, pleochroic biotite, right angle cleavage of pyroxene and rounded grain of quartz (Fig. 4.3). The rock shows gneissic banding. It is tentatively classified as a Biotite Gneiss.

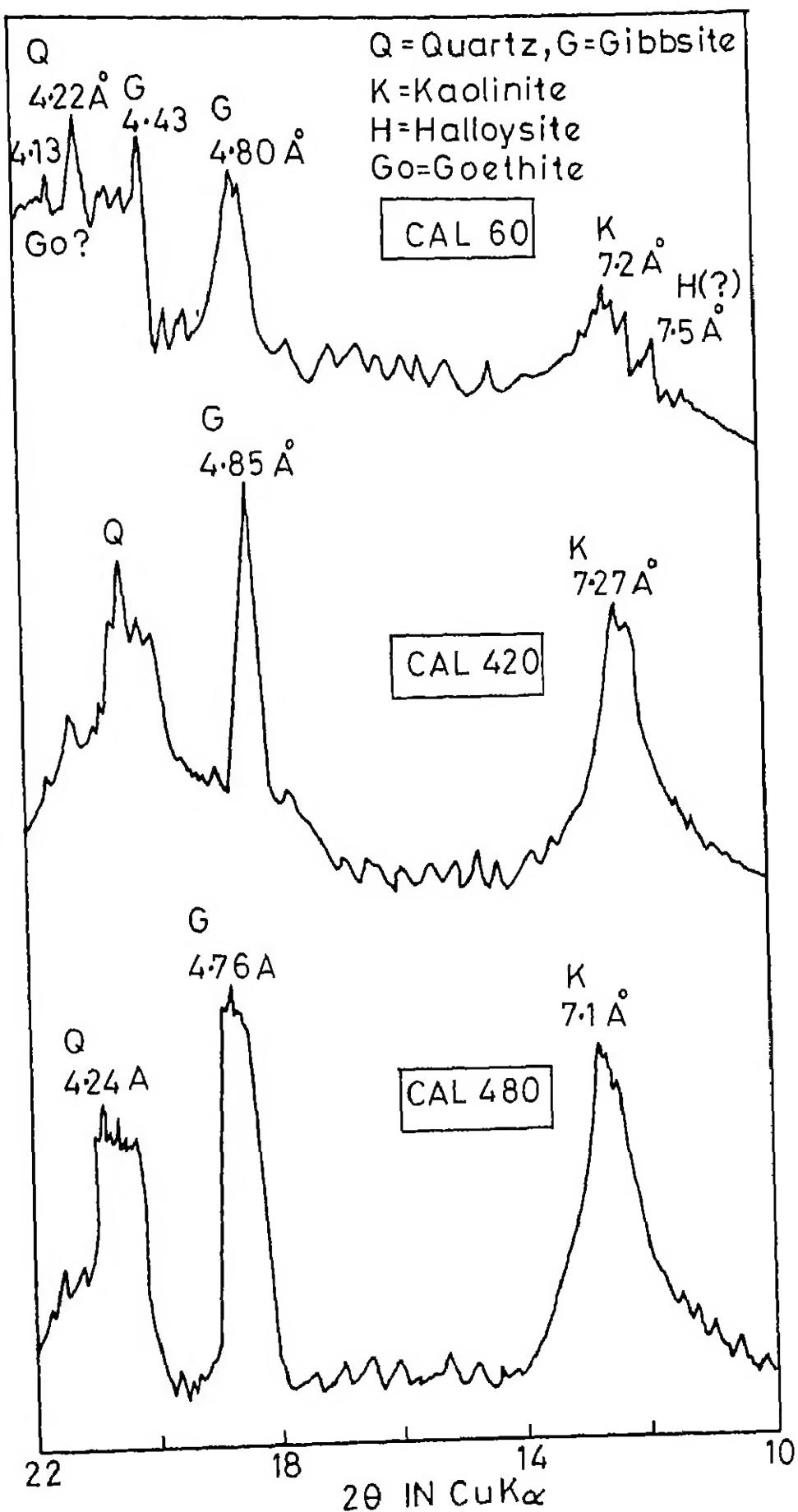


Fig. 4.2

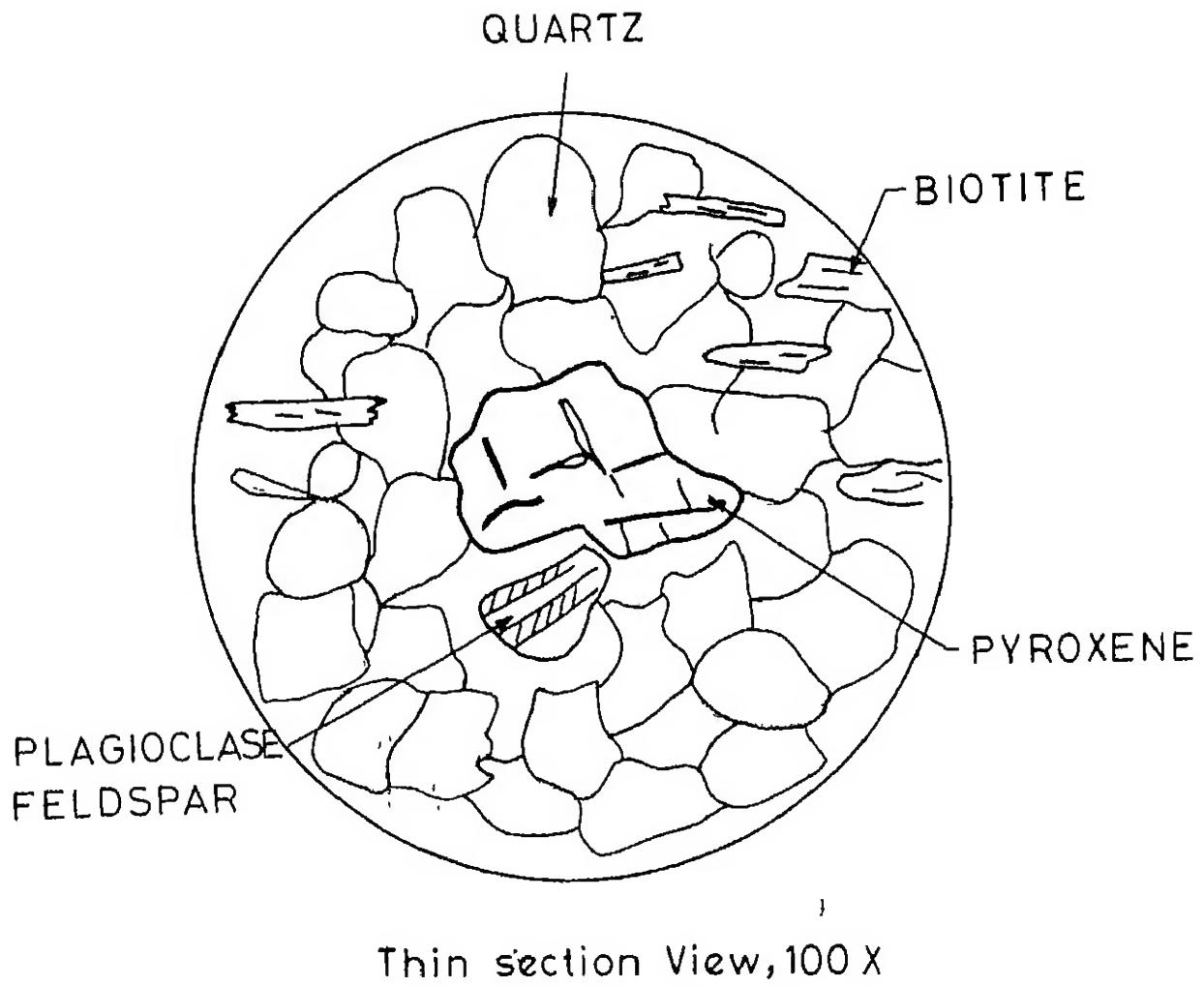


Fig. 4.3

4.2.2 GRAIN SIZE VARIATION :

This feature was analysed under two heads (1) Percentage retained on sieve No. 200 called the coarse fraction and (2) Percentage of the less than $2\text{-}\mu$ particle size called the clay fraction. The variation of these two parameters with depth in profile L-I&L-II is shown in Table 4.1.

Table 4.1

	COARSE FRACTION %	CLAY FRACTION %
Cal 60	40.2	34.7
Cal 420	30.0	47.6
Cal 480	29.9	53.2
Cal 190	62.3	13.2

It is apparent from these data that cementation of soil particles by iron oxide toward the top of laterite zone results in a progressive increase in the coarse fraction and a complementary decrease in the clay fraction. This supports the observation made earlier that the X-ray peaks of the clay minerals are suppressed by iron oxide coating toward the top of the laterite soil profile.

4.2.3 NATURAL MOISTURE CONTENT :

As shown in Table 4.2, moisture contents at different

depths of Profile L-I show a decreasing trend towards the top. As evaporation is maximum at the top soil, the moisture content is relatively lower than at the other two deeper horizons (Cal 420 and Cal 480). Clay has greater ability of retaining

Table 4.2

MOISTURE CONTENT %	
Cal 60	10.07
Cal 420	20.48
Cal 480	24.75
Cal 190	16.81
Cal 265	1.49

water as its permeability is comparatively less. As shown in Table 4.1, there is an increase in clay content with depth and the result of the moisture contents agree with the above argument. In Profile L-II the moisture contents of 'b'-horizon and 'c' horizon was determined through samples Cal 190 and Cal 265 respectively. The partly weathered rock('c' horizon) is highly permeable and has much less ability of retaining water than the 'b' zone with its relatively high clay content.

4.2.4 SATURATION MOISTURE CONTENT :

At the interface of bed rock and partly weathered rock ('c' horizon) there are certain small scale changes in the

physical properties of the fresh rock. Hamrol (1961) devised a weatherability index based on quick absorption test which consisted of soaking a rock sample in water and determining its saturation moisture content. Details of the test has been given in Chapter 3. The observation is that as a rock is progressively weathered it develops cracks and fissures and looses cohesion and therefore it is able to absorb greater quantities of water. The weatherability index defined as

$$\frac{\text{Wt. of sat. sample} - \text{Wt. of dry sample}}{\text{Wt. of dry sample}} \times 100$$

is equal to 2.03 for the bed rock of Profile L-II and 6.76 in the partly weathered zone at 2.65 m depth. As expected, the index of weathering increases from the bed rock to the 'c' horizon.

4.2.5 ORGANIC MATTER CONTENT :

The variation of this feature with depth in Profiles L-I and L-II is given in Table 4.3. The organic content at 60 cm depth in Profile L-I is high whereas at greater depths of 4.2 m or 4.8 m, no organic matter was detected. As the source of organic matter in soils is mainly from plants and the quantity of plant matter decreases with increasing soil depth, this result is expected.

Table 4.3

ORGANIC MATTER CONTENT	
	%
Cal 60	13.6
Cal 420	NOT DETECTED
Cal 480	NOT DETECTED
Cal 190	7.5

Though the sample from 'b' horizon of the Profile L-II is nearer to the weathered zone, organic matter content is found to be 7.5%. The depth at which this sample is taken is at a relatively shallow depth of 1.9 m. So, plant roots may be present to contribute to the organic matter content.

4.2.6 SOIL pH :

The near surface sample Cal 60 has a soil pH of 7.4 in 1:4 suspension. The pH decreases slightly to 7.3 in the laterite zone at 4.2 m.

4.2.7 CATION EXCHANGE CAPACITY :

The cation exchange capacity (CEC) of soil mainly depends on organic matter content, clay content and type of clay of the soil. Profile L-I was studied through two samples collected from upper and deeper surfaces at 60 cm and 4.2 m respectively. The CEC of the natural soil at 60 cm is 32.1 meq/100 gm but this drastically goes down to 6.4 meq/100 gm when the organic matter

Table 4.4

CEC in meq/100	
Cal 60 (natural)	32.1
Cal 60 (without org.)	6.4
Cal 420 (natural)	12.8
Cal 190 (natural)	9.63

is removed by H_2O_2 treatment. For the soil at 4.2 m no organic matter is detected as discussed earlier and Table 4.4 indicates a CEC value for this soil being higher than that obtained for soil at 60 cm. without organic matter. As discussed in section 4.2.1, the type of clay in this profile is mainly kaolinite. Therefore the increase in CEC from 6.4 to 12.8 meq/100 gm is due to the higher clay content at 4.2 m. These values also fall in the range of CEC for kaolinite clay (5 to 15 meq/100 g). Cal 190 of profile L-II with organic content of 7.5% has a CEC value of 9.63 meq/100g.

4.3 INDEX PROPERTIES OF BLACK SOIL PROFILE (Profile III) :

4.3.1 MINERALOGY :

The X-Ray diffractogram of a typical sample of the black soil zone (P-2) of Profile III shows the characteristic peak of montmorillonite at 14.96 \AA which expands to 16.7 \AA after glycolation (Fig. 4.4). The other minerals present are sodic plagioclase (3.19 \AA) and pyroxene (2.99 \AA). The weathered

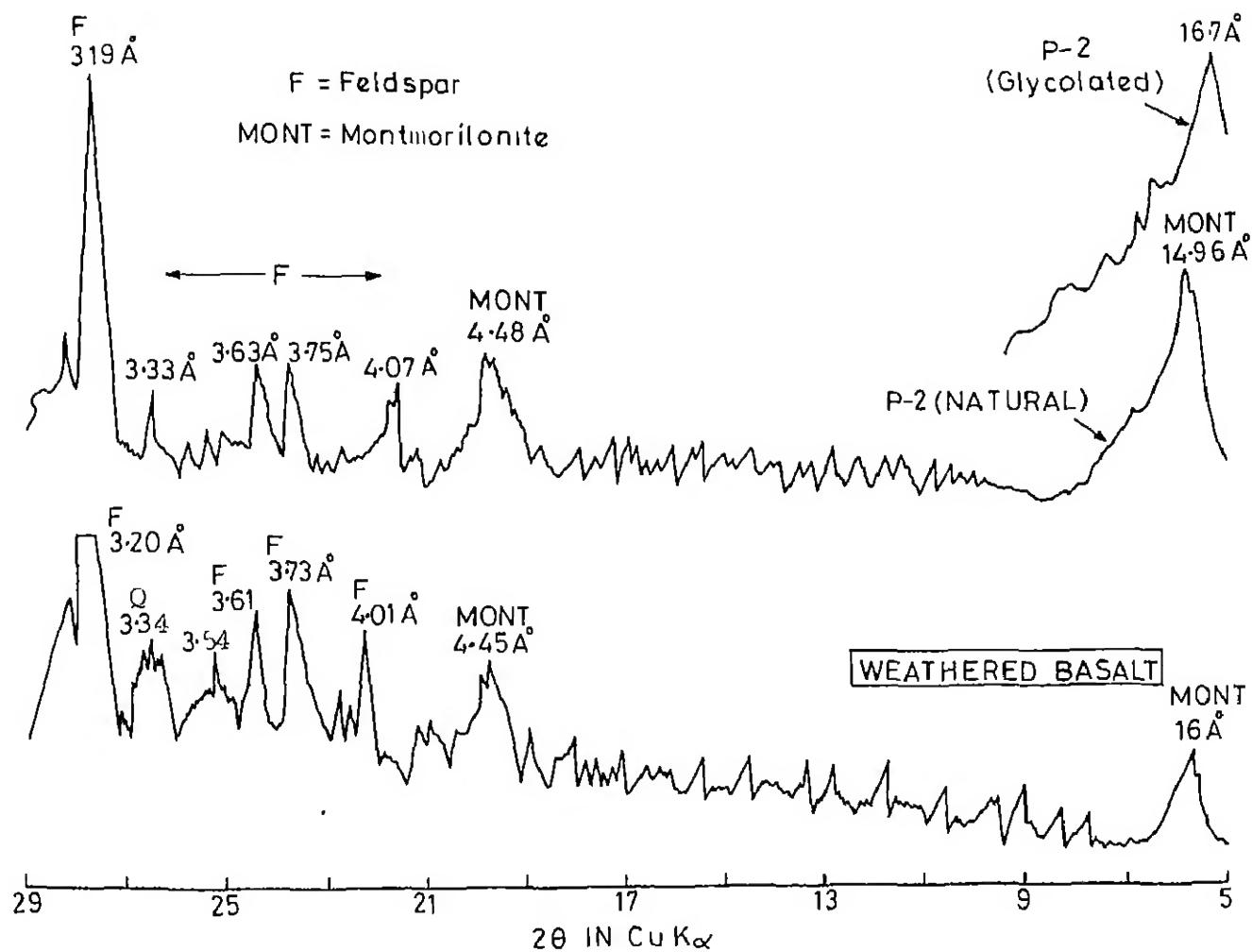


Fig. 4.4

basalt shows the montmorillonite peak along with prominent peaks of feldspar and pyroxene. The rock is quartz poor judging from the smallness of the 3.34° peak (Fig. 4.4).

4.3.2 GRAIN SIZE VARIATION :

Percentage retained on sieve No. 200, called the coarse fraction and percentage of the less than 2-micron particle size called the clay fraction of representative samples of Profile III are given in Table 4.5. It is clear from these

Table 4.5

	Depth (cm)	Coarse fraction %	Clay fraction %
P-1	15	14.7	30.7
P-2	90	20.0	20.0
P-3	195	24.67	11.7

data that the clay fraction decreases with depth resulting in the relative increase in the coarse fraction. As weathering is manifested in the formation of clay minerals, here it can be said that the top soil which is exposed to the atmosphere is most weathered.

4.2.3 MOISTURE CONTENT :

As the black soil samples were obtained from the Geology Department of Pune University and not collected by us in the

field, no attempt was made to determine their natural moisture content. However, the saturation moisture content of the weathered Basalt, determined by Quick Absorption Test, showed a value of 18% which is much higher than 6.76% in the c-horizon of Calicut Laterite. This is obviously due to the presence of montmorillonite in this zone. It is well known that the Liquid Limit of Black Soils is much higher than that of Laterite soils.

4.3.4 ORGANIC MATTER CONTENT :

The organic matter content is highest in the top soil and decreases with depth as shown in Table 4.6.

Table 4.6

	DEPTH (cm)	ORGANIC MATTER CONTENT %
P-1	15	10.1
P-2	90	9.6
P-3	195	9.6

This pattern can be explained by the presence of greater remains of plant matter in the root zone.

4.3.5 pH :

Sample P-1 collected at 15 cm depth has a soil pH value of 8.0 in 1:4 suspension. The value at 195 cm depth is 8.1. These pH values are higher than those obtained for the Calicut

laterite. This difference may be due to the presence of montmorillonite in the black soil. Kaolinite in laterite soils is known to form under relatively acidic environment.

4.3.6 CATION EXCHANGE CAPACITY :

The cation exchange capacity shows a decrease with depth. The values are tabulated in Table 4.7. The CEC of the natural

Table 4.7

	DEPTH (cm)	CATION EXCHANGE CAPACITY meq/100 gm
P-1	15	89.7
P-1 (without org. matter)	15	64.1
P-2	90	83.3

soil was determined in the two samples namely P-1 at 15 cm and P-2 at 90 cm depth. [The results are shown in Table 4.7.] The natural soil at 15 cm. has a CEC of 89.7 meq/100 gm. When the organic matter was removed by H_2O_2 treatment, CEC value was reduced to 64.1 meq/100 gm. At 90 cm depth, the organic matter content is 9.6% compared with 10.1% at 15 cm. The CEC value shows a corresponding decrease from 89.7 meq in sample P-1 to 83.3 meq/100 gm in sample P-2. The CEC values of the natural soil fall in the range predicted for montmorillonite clay (80-150 meq/100 gm) which is the main clay type in these soils.

CHAPTER 5

DISCUSSION

The results described in the previous chapter can be synthesized to compare the laterite soil profiles with the black soil profile. The obvious difference is mineralogy. Although the main minerals in the bed rocks for both profiles are feldspar & pyroxene, the black soil is dominated by montmorillonite and the laterite soils contain kaolinite and gibbsite. As discussed in earlier chapters, formation of kaolinite and gibbsite with iron oxide represents an advanced stage of weathering. At an intermediate stage particularly under poor drainage conditions montmorillonite is the product of weathering. Broadly speaking, therefore, the mineralogy of the laterite soils at Calicut indicates that the profiles are at a more advanced stage of weathering compared to the black soil profile near Pune.

The presence of iron oxide in colloidal and X-Ray amorphous state within the laterite soil profiles creates aggregation of soil particles. This leads to an increase in the coarse fraction and the complementary decrease in the clay content towards the top of the soil profile. Thus in laterite soil profiles, clay content alone is not a sufficient criterion to identify progressive weathering from bed rock to the top

soil. In the black soils, in contrast, increasing weathering towards the top gives rise to continuously increasing clay content. The common criterion of using the secondary clay mineral content as an index of weathering will be valid for black cotton soil but will be misleading for laterite profiles. As tropical weathering progresses, the, primary silicate minerals break down to montmorillonite clays at an intermediate stage. With further removal of silica and cations, kaolinite, gibbsite and iron hydroxides are the end products. The clay zone is ultimately overlain by a gravelly iron oxide rich layer where iron oxide cement causes grain clusters.

The natural moisture content in the laterite Profile L-I is lowest in the top soil possibly because of loss through evapo-transpiration in the root zone. However the 'c'-horizon exposed in Profile L-II is relatively dry compared to the laterite zone above. The saturation moisture content of the 'c' horizon in the laterite profile is much lower compared to that in the weathered basalt.

The pH of laterite soil is around 7. As shown in Fig. 2.1, this is in the range theoretically predicted for removal of SiO_2 and accumulation of Fe(OH)_3 and Al(OH)_3 . The pH of black soil is higher being around 8. This supports the view that kaolinite forms under more acidic environment compared to montmorillonite.

This study indicates that cation exchange capacity of both laterite and black soils is a dependent variable being a function of clay type, clay content and organic matter content. As Table 5.1 shows, laterite soils with kaolinite and gibbsite have much lower CEC values compared to the black soils containing montmorillonite. The soil at 60 cm depth in laterite Profile L-I containing 34.7% clay and 13.6% organic matter has a CEC value 32.1 meq/100 gm. In comparison, the black soil at 15 cm depth containing 30.7% clay and 10.1% organic matter has a CEC of 89.7 meq/100 gm. On removing the organic matter by H_2O_2 treatment, the reduction in CEC is $(32.1 - 6.4) / 13.6 = 1.88$ milli-equivalents

Table 5.1

	CLAY TYPE	CLAY CONTENT %	ORGANIC MATTER %	CEC meq/100 gm
Cal 60	Kaol + gibbsite	34.7	13.6	32.1
Cal 60 (without org. matter)	"	"	0	6.4
Cal 420	"	47.6	NOT DETECTED	12.8
Cal 190	"	13.7	7.5	9.6
P-1	Mont.	30.7	10.1	89.7
P-1 (without org. matter)	"	"	0	64.1
P-2	"	20.0	9.6	83.3

per one percent organic matter for laterite soil. Similarly, the reduction in CEC in the black soil is $(89.7-64.1)/10.1=2.53$ milli-equivalent per one percent organic matter from the black soil. As organic matter content decreases with depth in both soil profiles, CEC also shows sympathetic reduction. It can, therefore, be concluded that the CEC value of a tropical soil profile (laterite or black) will be maximum near the surface. However, the principal controlling factor is the clay mineral type. For any application in agriculture or waste removal, the montmorillonite rich soils would be most effective in adsorbing positively charged cations.

REFERENCES

ALEVA, G.J.J. (1981): Laterite Versus Saprolite. International Geological Correlation Programme (IGCP) Project-129: Lateritisation Processes. Newsletter-II, Hyderabad, India, pp. 30-34.

CARROLL, D. (1970): Rock Weathering New York, Plenum Press, 1970.

FOTH, H.D. (1984): Fundamentals of Soil Science 7th ed., John Wiley & Sons, New York.

GIDIGASU, M.D. (1976): Laterite Soil Engineering. Elsevier Scientific Publishing Company, New York.

GRIM, R.E. (1953): CLAY MINERALOGY. McGraw Hill Book Co., New York.

HAMROL, A.A. (1961): Quantitative Classification of the Weathering and Weatherability of Rocks. Proc. Int. Conf. Soil Mech & Found. Eng. 5th, Paris, 2: pp. 771-774.

INDIAN STANDARD, (1967): Methods for Test of Soils, IS: 27 20 (part XXIV). Determination of Base Exchange Capacity. Indian Standards Institution, New Delhi.

JACKSON, M.L. (1958): SOIL CHEMICAL ANALYSIS. Constable & Co. Ltd., London.

KRAUSYOPP, K.B. (1979): Introduction to Geochemistry. 2nd Edn., McGraw Hill Kogakusha, Tokyo.

LUNKAD, S.K. and RAYMAHASHAY, B.C. (1978): Ground Water Quality in Weathered Deccan Basalt of Malwa Plateau, India. Q. Jl. Engg. Geol. Vol. 11, pp. 273-277.

QIA, S.A. (1978): 'The Geotechnical Properties and behaviour of Stabilized Laterite Soils", Q.J. Engg. Geol., Vol.11, pp. 145-160.

RAO, T.V. and Krishna Murthi, G.S.R. (1985), "Mineralogy and Genesis of Soils of Red and Black Complex of Hyderabad, India". In Products and Processes of Rock Weathering, Recent Research in Geology, Vol. 11, pp. 225-247. Hindustan Pub. Corp., Delhi.

RAO, K.S. and RAYMAHASHAY, B.C. (1981): Influence of Clay Minerals and Iron Oxides on Selected Properties of Two Lateritic Soils. Indian Geotechnical Journal, Vol. 11, No. 3, pp 255-266.

RAYMAHASHAY, B.C., RAO, K.S., MEHTA, V.K. and BHAVAN, P.R. (1985) Mineralogy and Geochemistry of Laterite Soil Profiles in Kerala, India. Proc. International Seminar on Laterite, Tokyo, pp. 293-298.

TARDY, Y. (1971): Characterization of the Principal Weathering Types by the Geochemistry of Waters from Some European and African Crystalline Massifs. Chem. Geol. Vol. 7, pp. 253-271.

92031

